

ULTRASONIC EVALUATION OF LOW DENSITY POWDER COMPACTS

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INTRODUCTION

Ultrasonic evaluation of powder compacts provides valuable information about the density of the powder and incipient defects in the compact. Since the specimens would be contaminated if they were inspected with traditional immersion or contact techniques, procedures to dry couple or vacuum bag and immerse the powder samples were implemented. With these methods ultrasonic energy was propagated through the powder compacts and the acoustic velocity and attenuation were measured. The ability to immerse the powder samples not only provides consistent coupling but allows scanning which is a valuable tool to image variations and defects in the compacts.

Table 1. - Powder Specimens

Specimen	ID	Fractional Density	Length(cm)	Velocity (cm/usec)
<u>First Lot</u>				
A	JES-1731-1-12	0.28	0.927	0.011
B	JES-1731-1-4	0.35	0.744	0.047
C	JES-1731-1-7	0.43	0.604	0.075
D	JES-1731-1-9	0.48	0.546	0.095
E	JES-1731-1-13	0.84	0.307	0.277
<u>Second Lot</u>				
F	JES-1733-1-4	0.36	0.731	0.049
G	JES-1733-1-6	0.41	0.629	0.068
H	JES-1733-1-9	0.64	0.414	0.169
I	JES-1733-1-10	0.78	0.332	0.239
J	JES-1733-1-11	0.85	0.304	0.276

SAMPLE PREPARATION

A total of ten specimens were prepared for this study. Two lots of powders were pressed into five samples each. The fractional densities varied from 0.28 to 0.85 as shown in Table 1. These samples were intended to serve as references for quantitatively measuring the fractional density with ultrasonic techniques. But, after scanning the samples and imaging with the backwall reflection, it was noted that some of the specimens were not uniform. Thus some error was introduced into the acoustic property measurements. Also each sample is a different length which necessitated the correction for path length and may have contributed to errors for data taken with the focused transducers (2.25 and 5 MHz).

Compacts were prepared from one micrometer diameter powders which clustered together into approximately ten micrometer bunches [1]. Voids on the order of ten microns formed between the clusters. As illustrated in Figure 1, the entire structure is rather complicated.

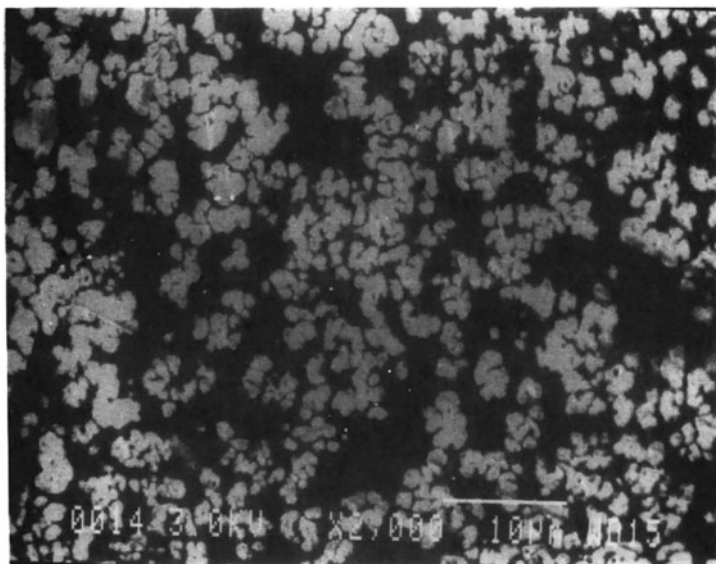


Fig. 1. Scanning electron micrograph of the microstructure of a powder compact.

ULTRASONIC DATA ACQUISITION

Before the powders could be ultrasonically evaluated a noncontaminating method to couple the acoustic energy into the part had to be developed. This was accomplished two ways. First a fixture was built to hold the specimens at a fixed load between two dry contact transducers, see Figure 2. A special rubber face plate on the transducers coupled

the acoustic energy into the powder. Matching transducers were configured so that data could be acquired in pulse-echo or through-transmission. Through-transmission was necessary for interrogating thick, low density compacts. A second method sealed the samples in a vacuum bag so that the specimens could be immersed in water and interrogated with traditional ultrasonic techniques. Ultrasonic data was acquired with three transducers which provided center frequencies at 1, 2.25, and 5 MHz. The transducers were excited with a Panametrics 5058 PR pulser/receiver in both arrangements. This pulser was designed for applications where low frequency and high voltages are appropriate. Ultrasonic signals returning from the compacts were digitized and passed to a microVAX for extensive processing.

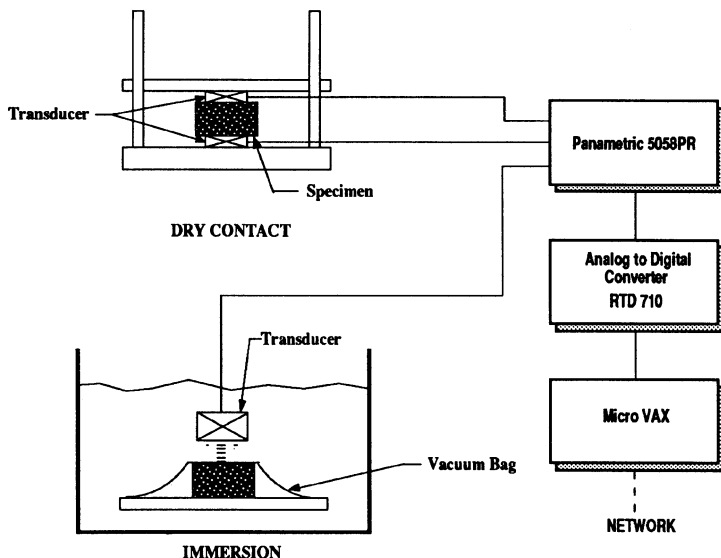


Fig. 2. Diagram of ultrasonic facility for coupling acoustic energy into powder compacts.

RESULTS

Powder compact characteristics were determined with three ultrasonic techniques: scanning and imaging, acoustic velocity measurement, and attenuation measurement in the frequency domain. High resolution ultrasonic C-scans were performed on the specimens to ascertain the uniformity of the compacts. The compact was insonified at normal incidence with the peak amplitude of the back surface reflection recorded at each location. As shown in Figure 3, the powder compacts are not always uniform. Figure 3a shows a uniform powder compact. But figure 3b displays a high density, low attenuation inclusion slightly off center. The image in Figure 3c which is from a different powder lot than the

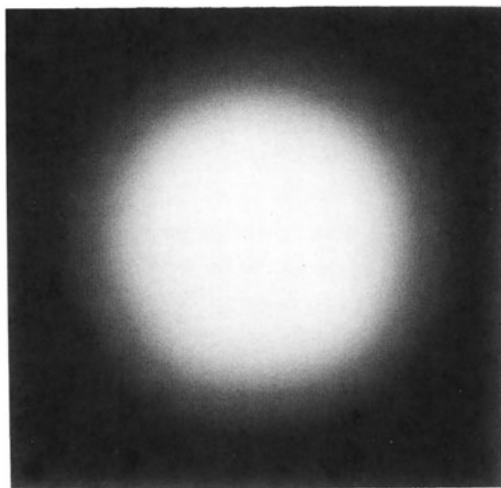


Fig. 3a-c. High resolution C-scan of three powder compacts (imaging backwall reflection).

Fig. 3a. Uniform powder compact from Lot 2. (0.64 fractional density)

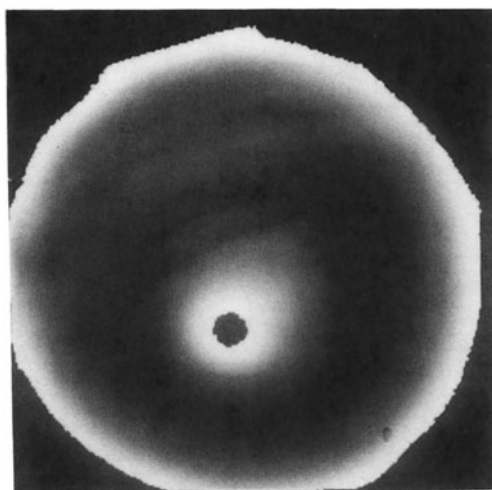
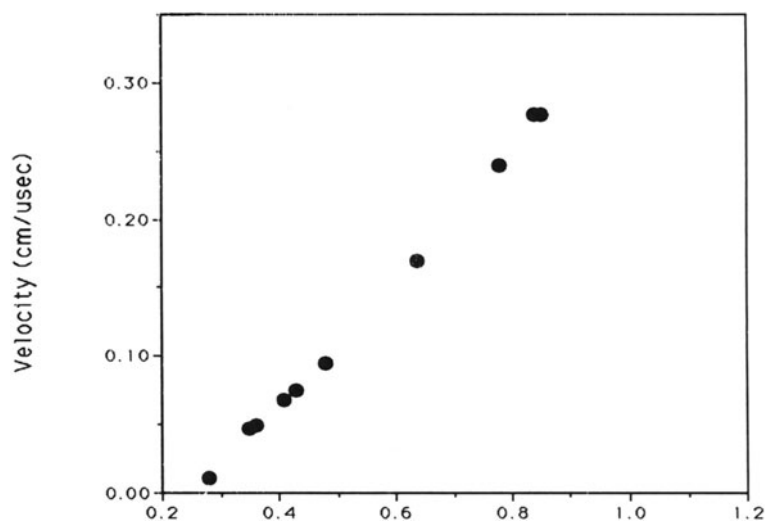
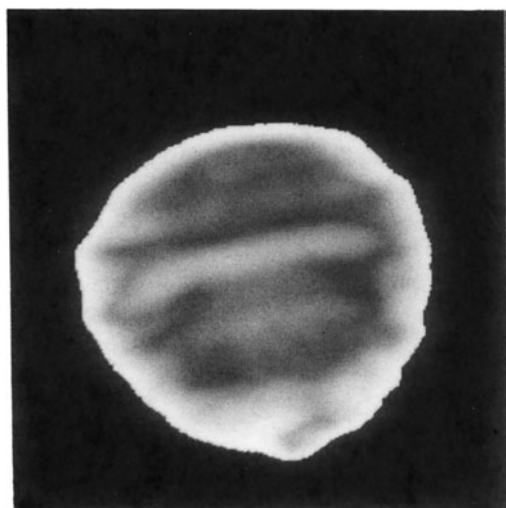


Fig. 3b. Powder compact with high density, low attenuation inclusion slightly off center from Lot 2. (0.36 fractional density)



specimens in Figures 3a and b, shows a slight cross-sectional variation. Since the acoustic velocity and attenuation measurements were taken at the center of each specimen, these nonuniformities will contribute to the error in the measurements.

The time of flight between the top reflection and the back wall reflection was measured and the acoustic velocity for each specimen was calculated. These velocities are listed in Table 1 and plotted in Figure 4. The linear relationship between acoustic velocity and fractional density provides the means for determining powder density from an ultrasonic measurement.

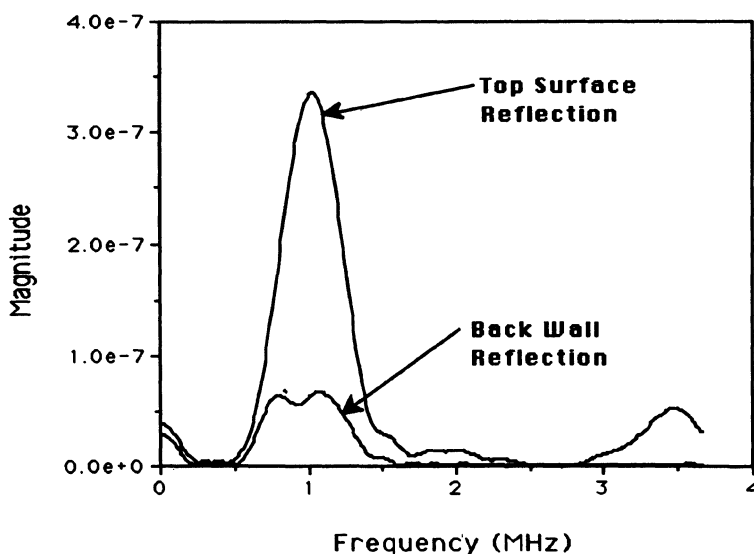


Fig. 5. Frequency content for 1 MHz transducer, 0.64 fractional density.

More information about the powder compact can be obtained by analyzing the ultrasonic interaction in the frequency domain. The frequency content of the top reflection which serves as a reference and the frequency content of the bottom reflection were compared to determine attenuation and other frequency related phenomena. For example, Figures 5, 6, and 7 are the spectra for the 0.64 fractional density specimen for the 1 MHz, 2.25 MHz, and 5 MHz transducers, respectively. As expected, there is a noticeable increase in attenuation as the frequency increases. The relation between attenuation and fractional density is plotted in Figure 8. Figure 8 shows the attenuation measured with both the 1 MHz transducer and the 5 MHz transducer. There is a greater attenuation at 5 MHz which provides more sensitivity to density change at the higher densities. Conversely, the one MHz transducer was needed to measure attenuation in the low density compacts.

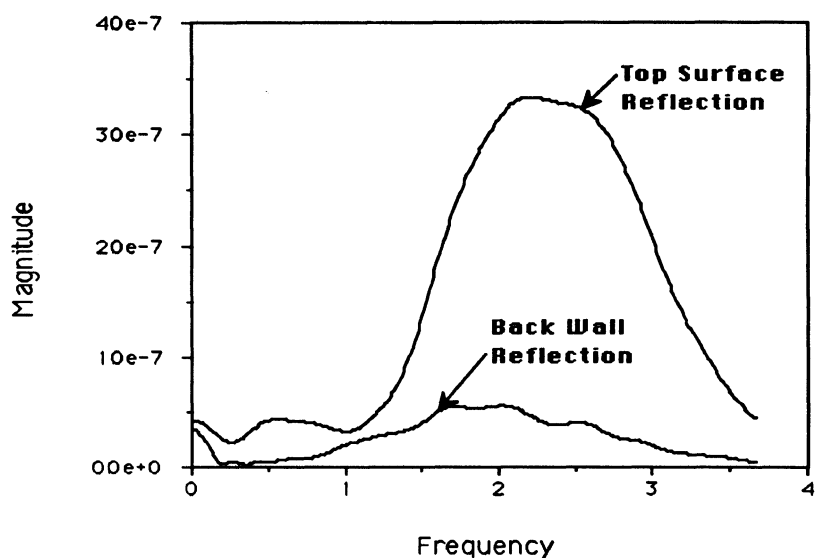


Fig. 6. Frequency content for 2.25 MHz transducer, 0.64 fractional density.

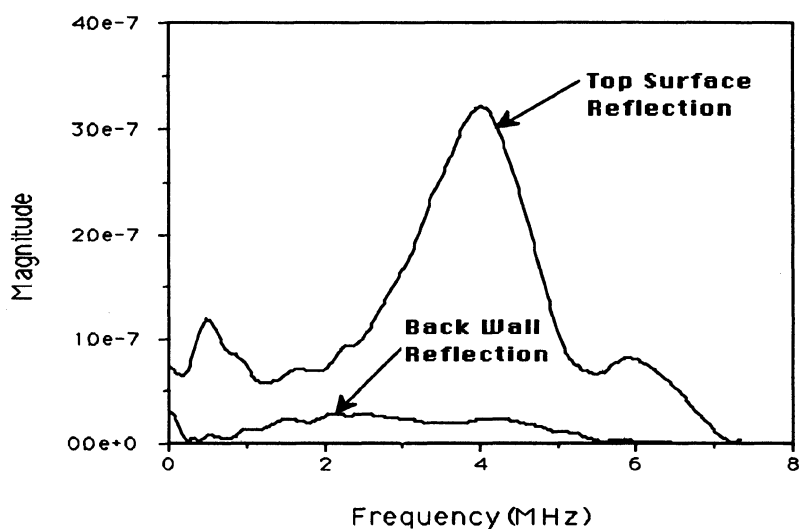


Fig. 7. Frequency content for 5 MHz transducer, 0.64 fractional density.

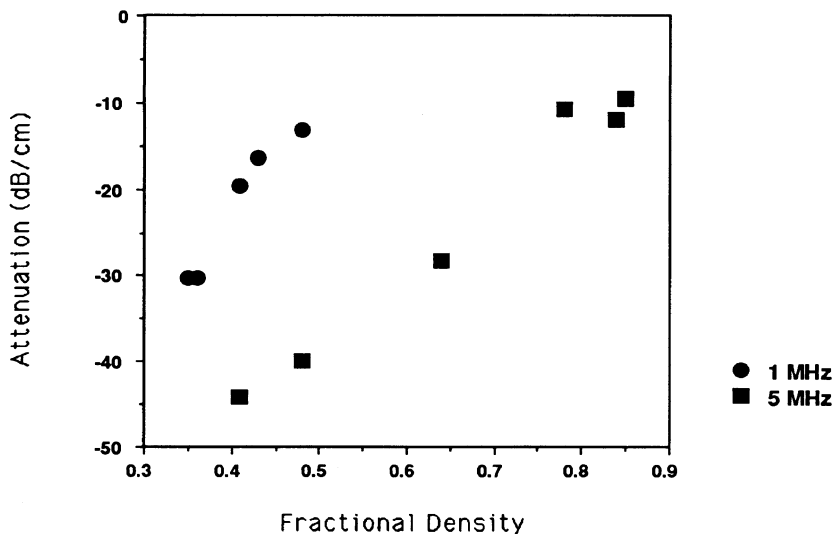


Fig. 8. Attenuation as a function of fractional density for the 1 MHz and 5 Mhz transducers.

SUMMARY

Ultrasonic nondestructive evaluation is a valuable tool for investigating the density and uniformity of powder compacts. Once techniques were developed to couple the acoustic energy into the powder without contamination, ultrasonic measurements of velocity and attenuation correlated well with powder density. High resolution scanning of the specimens imaged the internal structure and displayed variations in the compacts. Theoretical modeling of this complex structure and its interaction with the ultrasonic energy is needed to help quantify our experimental results.

ACKNOWLEDGMENT

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REFERENCE

1. J. E. Smugeresky, Sandia National Laboratories, Livermore, California 94551, personal communication.